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AIR POLLUTION AND VEGETATION. II. EFFECTS OF FERTILIZATION ON GROWTH AND DEVELOPMENT OF TWENTY WOODY PLANTS GROWN IN INDUSTRIAL AREAS

Atle Habjorg

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AIR POLLUTION AND VEGETATION
II. EFFECTS OF FERTILIZATION ON GROWTH AND DEVELOPMENT OF TWENTY WOODY PLANTS GROWN IN INDUSTRIAL AREAS
[Luftforurensning og vegetasjon II. Virkninger av gjødsling og kalking på vekst og utvikling av 20 lignoseslag dyrket på sterkt SO_2-eksponert sted i Sarpsborg]

By

Atle Håbjørg

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I. Introduction

The problem of pollution and its harmful effects on human beings, animals and plants is nothing new. As early as in 1853, Stöckhardt [7] showed that industrial smoke led to acute damage to vegetation, and that SO_2 was the most active substance in the smoke. Since that time, SO_2 discharges have increased tremendously. The reason for this is first and foremost the great expansion of industry, the growth of densely populated areas and

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the use of oil for heating. In some places the SO_2 concentration in the air has become so high that practically speaking all vegetation has died. This is partly the result of direct damage to leaves and partly the result of indirect damage due to unbalanced nutrient conditions in the soil [2]. Extreme soil conditions are due to the fact that the sulfur dioxide in the air oxidizes to sulfur trioxide which together with water forms sulfuric acid. When it reaches the soil, it is neutralized by an exchange of cations (Ca, Mg, K, Fe, Al, etc.) which are then carried away by seepage [4]. This indirect damage is therefore expressed in deficiency diseases: small, yellowed, deformed leaves.

Vegetation constitutes an important element in all industrial and built-up areas. Not primarily for its aesthetic value, but mainly because of the environmental improvements to which it leads. Along heavily traveled roads it can be used as a noise-damping element, and in order to catch impurities [5]. Large woody plants in towns and industrial areas will take up impurities and in this manner contribute to "purifying" the air. It is therefore important to discover which plants can tolerate such conditions. The purpose of our experiments was to investigate the direct and indirect harm of SO_2 to 20 woody plants. We also attempted to discover resistant woody plants and how damage to these can be reduced with the aid of fertilization.

II. Method

The experiments were conducted in Museum Park, Sarpsborg, and on the plantation of the Institute of Dendrology and Nursery Management of the Agricultural University of Norway (AUN). Two different types of soil were used in the experiments. The one was taken from a SO_2-exposed place in

Sarpsborg, and the other consisted of a mixture of unfertilized peat and powdered basalt.

The plants were potted in plastic containers, each with about 1 liter soil. After potting, the containers stood 2-3 weeks at the AUN before they were put in the places of growth. In Museum Park the containers were put on a thin layer of peat while at the AUN they stood on bare plastic. In Sarpsborg the plants were tended by employees of the Department of Parks.

Four times in the course of the growing season notes were taken about leaf damage. The plants from the AUN were then transported to Sarpsborg for direct comparison with the plants there. At the end of the experiment the plants were weighed and measured.

III. Experiments

A. Resistance Experiment with Twelve Woody Plants

The experiment was conducted in Museum Park in Sarpsborg. As growth medium we used a mixture of unfertilized peat and powdered basalt. To the soil three different amounts of dolomitic limestone were added: 0, 2 and 4 kg per m^3. The nutriment content is shown in Table 1. In the growing season it was fertilized every 14 days with two different amounts of fertilizer B: 1 and 3°/oo. The experiment began on the 30th of May and was terminated on September 11, 1969.

Table 1. Analysis of the mixture of powdered basalt and unfertilized peat.

a kg dolomittmjøl pr. m^3 jord	pH	P-AL	K-AL	Ca-AL	Mg-AL
0	6,6	2,7	10	440	13
2	6,9	3,4	11	520	44
4	7,1	3,5	11	580	90

Key: 1. kg dolomitic limestone per m^3 soil.

[Translator's note: Commas in numerals are equivalent to decimal points.]

Table 2. Effect of fertilization on sulphur dioxide damage to trees and shrubs. 0 = no visible damage. 10 = dead.

Art.[a]	Fullgjødsel B[b]	
	1‰	3‰
Alnus incana	6	4
Amelanchier sp.	3	0
Betula pubescens	4	2
Cornus 'Sibirica'	5	0
Cotoneaster lucidus	3	1
Elaeagnus commutata	0	0
Hippophaë rhamnoides	2	0
Picea abies	3	1
P. pungens 'Glauca'	1	0
Pinus silvestris	5	2
Syringa vulgaris	1	0
Ulmus glabra	5	1

Key: 1. Species
2. Fertilizer B

Results: In this experiment, liming led to no significant difference in leaf damage but, on the other hand, fertilization had a pronounced effect (Table 2). All plants showed considerably less leaf damage for the strong concentration of fertilizer as compared with the weak concentration. This was especially evident in the case of Cornus 'Sibirica,' Ulmus glabra and Pinus silvestris (Fig. 1). The least damage and therefore the greatest SO_2 resistance was shown by Elaeagnus commutata, Picea pungens 'Glauca,' Syringa vulgaris and Hippophaë rhamnoides.

B. Resistance Experiment with Twenty Woody Plants

The experiment was conducted in Sarpsborg and at the AUN. Two different types of soil were used: soil from Sarpsborg and a mixture of unfertilized peat and powdered basalt. To the soil three different amounts of dolomitic limestone were added: 0, 2 and 4 kg/m^3. To the mixed soil, moreover, 2 kg 8% superphosphate per m^3 soil were added. This soil was not fertilized. In order to meet the food requirements of the plants in the growing season, they were fertilized every 14 days with 3‰ fertilizer B as well as a

Fig. 1. Effect of fertilization on growth of Cornus 'Sibirica.'
Left: 1°/oo fertilizer B
Right: 3°/oo fertilizer B

mixture of micro-foodstuffs. The nutriment content of the soil at the start of the experiment is shown in Table 3.

Table 3. Analysis of the mixture of powdered basalt and unfertilized peat, and of SO_2-exposed soil from Sarpsborg.

kg dolomit-a mjøl pr. m³	Sarpsborg-jord b				Blandingsjord c			
	pH	P-AL	K-AL	Mg-AL	pH	P-AL	K-AL	Mg-AL
0	6,5	93	20	11	6,4	30	11	19
2	6,8	95	20	23	6,7	38	11	50
4	6,9	98	19	31	6,8	40	12	92

Key: 1. kg dolomitic limestone per m^3 soil
2. Sarpsborg soil
3. Mixed soil

The experiment was started on May 28 and terminated on September 19, 1970.

Results: Table 4 shows the average dry weight of the plants. As can be seen from the table, the effect of liming, type of soil and place of cultivation on growth differed sharply from species to species. And according to observations of leaf damage to the plants in Sarpsborg, the variations in symptoms of damage were at least just as great.

Alnus incana (L.) Moench. Considerable leaf damage could be observed as early as 3-4 weeks after the plants were moved to Sarspborg. The damage first took the form of a slight yellowing of the leaf blade and a scorching at the leaf edge. The scorching spread rapidly all over the leaf, which became brown, curled up and finally fell off. The new leaves that developed were considerably more resistant, but at the same time much smaller and with pronounced chlorosis.

The maximum reduction in weight for the plants in Sarpsborg was 95% in Sarpsborg soil, but it was only 60% in mixed soil. The effect of the type of soil, which accounted for about 40% of the total reduction in weight, could almost be eliminated by adding nitrogen, potassium, calcium, magnesium and micro-foodstuffs (Fe, Mn, Cu and Zn). Dolomitic limestone had an especially great effect on the dry weight (Table 4). The effect of the place of cultivation was also great. The 60% reduction in weight in the case of the gray alders cultivated in Sarpsborg showed that the gray alder is among the most SO_2-sensitive of all the tested woody plants (Fig. 2).

Amelanchier sp. In the sweet cotoneaster pronounced leaf damage could be observed after 8-10 weeks, and then first as a scorching at the leaf edge. Later the leaves yellowed, and brown parts appeared on the leaf blade. Some of the leaves were so severely attacked that they fell off

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early, while the true leaf fall started 2-3 weeks earlier than usual, and then first in Sarpsborg soil. Autumnal color was lacking in the plants cultivated in Sarpsborg.

The effect of the type of soil was great: between 35 and 40% of the reduction in weight in Sarpsborg soil as compared with mixed soil. Under all circumstances the greatest growth was attained with moderate liming. The effect of the place of cultivation was also considerable. Plants cultivated in Sarpsborg had 25-30% less growth than those grown at the AUN.

Berberis thunbergii DC. The autumnal barberry showed slight symptoms of damage only after 3 months. The leaves were then somewhat paler than usual, and some red spots were spread over the entire leaf plate. There was no trace of scorching on the leaf, nor could we record at the end of the experiment any differencein growth between plants cultivated in Sarpsborg and those grown at the AUN.

The slight leaf damage that could be observed was most pronounced in Sarpsborg soil and therefore indicates a certain effect of the soil. This tendency however was not so great as to result in reduced growth. The effect of liming was not quite unambiguous in the barberry, but in every case the best growth occurred with 2 kg dolomitic limestone per m^3 soil.

In spite of the fact that neither place of cultivation nor soil had any particular effect on growth, it must be said that the ornamental value of plants cultivated in Sarpsborg was considerably reduced in that they did not acquire normal autumnal color.

Betula pubescens Ehrh. The birch is one of the most common trees in Sarpsborg parks, but just about every one of them is badly damaged. Damage

Table 4

Effects of dolomitic limestone and soil on dry weight in grams of plants cultivated in Sarpsborg and at AUN

a Art.	Kg dolomitmjøl pr. m³ jord b											
	Dyrkingssted c											
	Sarpsborg						NLH d					
	Sarpsborg-jord e			Blandingsjord f			Sarpsborg-jord			Blandingsjord		
	0	2	4	0	2	4	0	2	4	0	2	4
Alnus incana	1,9	2,2	2,4	3,6	3,8	3,7	10,4	14,0	15,1	15,7	20,4	17,5
Amelanchier sp.	9,7	11,8	8,4	11,1	20,7	14,0	10,4	16,6	12,6	24,7	25,5	16,3
Berberis thunbergii	15,0	12,6	11,3	14,5	17,0	9,2	13,5	14,2	12,7	11,6	17,8	10,7
Betula pubescens	7,4	10,6	9,8	9,4	14,8	12,6	11,2	12,6	12,5	18,4	16,8	11,2
Cornus 'Sibirica'	21,4	23,9	29,1	18,1	28,2	27,9	20,5	26,5	28,4	24,7	24,2	25,5
Cotoneaster lucidus	12,5	11,4	10,4	12,5	11,3	14,9	14,5	17,4	15,5	19,0	16,2	14,8
Crataegus sanguinea	14,6	13,6	11,8	15,6	12,6	11,1	19,6	16,6	13,9	20,5	18,7	17,3
Cytisus purgans	2,2	1,4	0,6	2,9	1,6	1,2	3,5	5,6	3,1	10,8	6,7	4,1
Elaeagnus commutata	16,8	24,3	38,6	20,8	35,1	24,8	31,8	32,8	16,9	34,5	29,2	17,0
Hippophaë rhamnoides	15,7	19,0	13,5	20,4	23,0	15,6	15,9	33,4	29,5	27,2	28,3	28,7
Lonicera morrowii	10,6	13,1	15,3	16,1	30,0	18,2	24,3	42,5	24,4	41,5	40,5	23,2
Potentilla 'Longacre'	22,2	29,8	34,1	31,8	35,3	48,9	35,3	41,3	38,0	52,7	43,9	41,2
Rosa 'Moje Hammarberg'	12,1	9,7	6,8	9,3	11,3	8,8	39,8	28,1	21,4	31,7	33,2	29,9
Sorbus aucuparia	13,6	11,7	5,7	13,9	20,8	22,3	28,2	34,0	19,3	30,8	33,8	30,4
Syringa vulgaris	12,0	18,4	18,9	12,9	23,0	13,7	14,2	18,9	18,0	18,0	22,5	10,0
Ulmus glabra	9,0	13,2	19,1	14,1	19,8	16,5	12,4	21,0	16,4	18,2	24,2	13,8

Key: a. Species
b. kg dolomitic limestone per m^3 soil
c. Place of cultivation
d. AUN
e. Sarpsborg soil
f. Mixed soil

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Fig. 2. Effects of place and soil on growth of Alnus incana.
From left: Plants grown in SO_2-exposed soil in Sarpsborg
Plants grown in SO_2-exposed soil at AUN
Plants grown in mixed soil in Sarpsborg
Plants grown in mixed soil at AUN

to the birch began as a mild yellowing of the leaf blade. In dry weather the yellowing became constantly more pronounced, until the leaf became yellow-brown and fell off. In damp weather a little scorching occurred at the leaf edge, and the leaf then became completely brown before leaf fall.

Elder trees became cracked, the bark was dark, and the plants' ornamental value was on the whole greatly reduced.

Leaf damage was typical of indirect damage and pointed to the powerful effect of the type of soil. In experiments in this connection it therefore came as no surprise to find that the growth of the plants in Sarpsborg soil was reduced by 25-30%. This seems to be due mainly to the

low cation content of the soil, but it was also significant that a high phosphorus content led to a considerable reduction in growth. By adding calcium, potassium, magnesium, nitrogen and micro-foodstuffs, and by reducing the phosphorus content, the effect of the soil could be practically eliminated.

The effect of the place of cultivation depended on the soil. In this experiment the growth of the Sarpsborg plants was on the average about 25% less than that of those at the AUN. Plants cultivated in Sarpsborg showed a considerably greater need for lime. Two kg dolomitic limestone per m^3 soil resulted in optimal growth, while the growth of the AUN plants was reduced with increasing liming in mixed soil.

Cornus 'Sibirica'. The Siberian dogwood showed considerable leaf damage only after an exposure time of 2 months. Damage began as scorching at the leaf edge, which gradually became completely brown. The leaf curled, the foliage became dark, and the lovely autumnal colors that normally occur were entirely absent.

The Siberian dogwood was one of the few plants where scorching of the leaves did not lead to reduced growth. At the end of the experiment, no effect of either place of cultivation or soil on total growth could be detected, but in this case too the ornamental value was greatly reduced by cultivation in Sarpsborg, where the plants did not acquire their normal autumnal colors.

Also in the case of this species the need for lime was greatest in Sarpsborg soil. In this case growth increased with increasing liming both at the AUN and in Sarpsborg. Liming had not effect in mixed soil at the AUN while growth was greatest for moderate liming in Sarpsborg.

Cotoneaster lucidus Schlecht. The glossy cotoneaster showed little leaf damage. The leaves darkened a bit, and a few brown spots occurred on the leaves of plants cultivated in Sarpsborg soil in Sarpsborg, but otherwise the shrubs on the whole kept their ornamental value except for the absence of autumnal colors.

The effect of the type of soil on growth was minimal. The reduction in growth in soil from Sarpsborg varied from 5 to 12%. It was greatest in plants cultivated in Sarpsborg. On the other hand, the effect of the place of cultivation was considerable. In Sarpsborg the plants showed in every case 25% less growth than at the AUN. According to these experiments, the growth of this species seems to be affected but little by the presence of lime in the soil.

Crataegus sanguinea Pall. The Siberian hawthorn showed the first symptoms of leaf damage about 2 months after exposure in Sarpsborg. Damage began as scorching at the leaf edge. The leaves became rough and gradually turned rather dark. Autumnal colors were lacking, and therefore the ornamental value was greatly reduced. The leaf damage that occurred in the Siberian hawthorn was a typical symptom of direct SO_2 damage. The experiments also showed that indirect damage was insignificant. In Sarpsborg the type of soil had no effect. On the other hand, the effect of the place of cultivation was pronounced. In every case the growth of the plants in Sarpsborg was about 25% less than that at the AUN. Of all the investigated species, the Siberian hawthorn was the only one for which liming under all circumstances led to reduced growth.

Cytisus purgans (L.) Spach. The Spanish broom showed considerable symptoms of damage as early as after 3-4 weeks, first as a slight yellowing

of the entire plant. Gradually the yellow color became more pronounced, and finally the plants were quite brown and dead. About 30% of the plants in Sarpsborg were dead at the end of the experiment.

Of all the investigated species, this was the one that reacted most violently both to type of soil and to place of cultivation. The reduction in weight in Sarpsborg soil was about 40%, and the growth of plants in Sarpsborg about 70%, less than at the AUN. In the case of this species, too, growth diminished in every case with increasing liming, but the tendency was not so clear as in the case of the Siberian hawthorn.

Elaeagnus commutata Bernh. These shrubs showed no visible damage to the foliage, but some of the oldest leaves fell off earlier than usual, so that the shrubs became sparse. No effect of either type of soil or place of cultivation could be detected, but noteworthy is the greater need for lime of the plants in Sarpsborg. While the growth increased with increasing liming in Sarpsborg, it decreased with increasing liming at the AUN (Table 4).

Hippophaë rhamnoides L. Nor did the buckthorn show visible damage to the foliage, but in this case, too, the oldest leaves fell off, so that the shrubs became sparse. Gradually the newly-developed leaves also became smaller than the normal.

The effect of the type of soil was relatively slight. The plants in Sarpsborg soil grew about 8-13% less than those in mixed soil. In every case, growth was greatest for moderate liming.

On the other hand, the effect of the place of cultivation was considerable. Plants cultivated in Sarpsborg grew about 35% less than those at the AUN.

Lonicera morrowii Gray. This plant showed pronounced leaf damage as early as after 4 weeks. The leaf blade became yellow-veined while the leaf nerves kept themselves dark green. This was especially conspicuous in the plants in Sarpsborg soil. These plants had already lost their leaves by August 25, at least 1 month before the plants in mixed soil. This points to the powerful effect of the soil. In this experiment it also turned out that the reduction in weight in Sarpsborg soil was as much as 40%.

The effect of the place of cultivation was also very great. Plants cultivated in Sarpsborg showed only half as much growth as those at the AUN. The plants cultivated in Sarpsborg also showed considerably greater need for lime. In Sarpsborg soil, the greatest growth occurred with the greatest liming and in mixed soil, with moderate liming. At the AUN the greatest growth in Sarpsborg soil occurred with moderate liming while in mixed soil it decreased with increasing liming.

Potentilla 'Longacre'. Leaf damage to the tormentil could first be observed after 2 months. At that time the leaf blade assumed a dark green color which kept on darkening, and growth became more compact. The reduction in weight in Sarpsborg soil varied between 15 and 25%, and the weight reduction in plants cultivated in Sarpsborg was about 20%.

In this plant, too, the need for lime in Sarpsborg was considerably greater than at the AUN. In Sarpsborg, growth increased with increasing liming while in Sarpsborg soil at the AUN, growth was greatest with moderate liming. In mixed soil growth decreased with increasing liming.

Rosa 'Moje Hammarberg' already showed clear symptoms of SO_2 damage by the fourth week. Damage was expressed as a weak yellowing of the leaf

blade followed by intensive yellow marbling. The leaves became rough and the dark green leaf nerves became very pronounced. The flower petals became scorched at the edges and fell off after a few days. The carpels were also so damaged that no fruition took place.

The effect of the type of soil on growth was insignificant while, on the other hand, the effect of the place of cultivation was very strong. Plants cultivated in Sarpsborg showed about 70% less growth than those cultivated at the AUN, which means that this rose is one of the most SO_2-sensitive plants of those investigated.

The reaction to liming was abnormal. In the case of most species the need for lime was greatest in Sarpsborg soil. In the case of 'Moje Hammarberg', on the other hand, growth decreased with increasing liming in Sarpsborg soil, while it was greatest for moderate liming in mixed soil.

Sorbus aucuparia L. Blade damage to the common rowan tree could be observed soon after 1 month, but only after 2 months did it show up clearly. By then the leaf edge was scorched quite brown, and the leaves were yellow-veined and very rough. The plants in Sarpsborg did not acquire their autumnal colors, and leaf fall occurred about 3 weeks earlier than in the case of the plants cultivated at the AUN. The growth of the plants in Sarpsborg was also about 50% less than that of those at the AUN.

The effect of the soil varied from 15 to 45%. The reduction in weight was greatest in Sarpsborg. There was no unambiguous effect of liming or soil.

Syringa vulgaris L. Leaf damage to the lilac bush could only be observed 3 months after exposure time. The tips of some leaves were scorched, and the edges of these leaves had bent back so that the leaves became bowl-shaped.

Type of soil and place of cultivation had about the same effect. Growth was from 25 to 35% less in Sarpsborg than at the AUN and correspondingly less in Sarpsborg soil as compared with AUN soil.

The effect of liming was very clear. No significant increase in growth could be obtained with amounts of lime in excess of 2 kg dolomitic limestone per m^3.

Ulmus glabra Huds. Leaf damage to the elm began as a slight yellowing of the leaf edge. The leaves became rough and gradually assumed a dirty color.

The effect of the soil was greater than that of the place of cultivation: 15-20 and 10-15%, respectively. Also in the case of the elm, Sarpsborg soil showed the greatest need for lime, and the need for lime was considerably greater in Sarpsborg than at the AUN.

Weigela 'Eva Rathke'. No significant leaf damage could be observed in this plant, but the leaves gradually decreased in size so that the leaves that developed later in the summer were only about 80-90% as big as normal leaves. The shrubs flowered at least as well in Sarpsborg as at the AUN, and there was no sign of scorching on the petals. Another variety that we observed also flowered well, without any sign of scorching.

As a flowering shrub Weigela was in a class by itself.

Picea abies (L.) Karst. During the course of the growing season no damage to the leaves of the common spruce could be observed, but older trees lost their needles earlier than usual, and the plants became thin and slouching. A considerable reduction in growth could be observed with increasing supply of dolomitic limestone. The effect of the soil was minimal, about 10% less growth in Sarpsborg soil than in mixed soil. The

effect of the place of cultivation was considerably greater. The plants in Sarpsborg showed 20-30% less growth than those at the AUN.

Picea pungens 'Glauca'. Nor did the blue spruce suffer any visible leaf damage, but older trees gradually lost their blue color, and the needles acquired a dark, almost dirty color. In this way the plants lost some of their ornamental value, but the blue spruce must nevertheless be recommended for use inasmuch as it is one of the few evergreens that can get along in places with a high SO_2 concentration in the air.

The effect of the type of soil was insignificant in the case of the blue spruce while, on the other hand, the effect of the place of cultivation was considerable. The cell elongation of the plants cultivated in Sarpsborg was reduced by 20-30%. The plants therefore became very compact in growth.

Pinus silvestris L. Leaf damage to the common pine was first observed as a slight yellowing of the needles, which gradually turned brown. Finally, the needles were completely brown, and by the following summer most of the one-year needles had fallen off.

Also in the case of the pine the effect of the soil was slight while the effect of the place of cultivation already in the first growing season was about 30%. The effect of the place of cultivation increased with exposure time. By the second year the reduction in weight of the plants in Sarpsborg had already increased to 60%. And the growth of the trees planted in Museum Park in Sarpsborg decreased every year until the plants after 3-5 years were quite dead.

C. Damage to the Foliage of Woody Plants in Sarpsborg Parks

In the beginning of August 1969 and 1970, we recorded leaf damage to woody plants in Museum Park. In judging this damage we used a scale from

0 to 10, with 10 representing the greatest damage. These observations do not give any exact picture of the SO_2 resistance of the different species because no two species were similarly exposed, but it will help to fill out the picture that we have formed of the SO_2 resistance on the basis of the resistance experiments. On the whole, the observations were taken from 150 to 200 m from the pollution sources.

	Damage
Abies alba	7
Abies grandis	10
Acer platanoides	2–3
A. pseudoplatanus	3–4
Berberis thunbergii	0–2
Betula pubescens	3–5
Cornus 'Sibirica'	1–3
Fraxinus excelsior	2
Parthenocissus quinquefolia	2
Picea abies	4–9
P. pungens 'Glauca'	1–3
Pinus silvestris	6–10
Populus balsamifera	5
Spiraea salicifolia	2
S. × *vanhouttei*	5
Syringa vulgaris	2–3
Tilia cordata	4–8
Ulmus glabra	6–8

IV. Discussion and Summary

In the last 10-15 years much attention has been devoted to the effect of air pollution on vegetation, and a great number of recordings have been made. The purpose of these recordings was first and foremost to chart the extent of damage and, in addition, to grade the species according to resistance [3, 6 and 8]. Very few researchers have had in view to discover methods to reduce the damage.

The present investigation, on the basis of experiments with liming, fertilization and type of soil conducted at a SO_2-exposed place in Sarpsborg and at the Agricultural University of Norway, has attempted to grade direct and indirect SO_2 damage in 20 species of woody plants.

As can be seen from Table 2, the effect of fertilization was quite unambiguous. In all species fertilization with 3 parts per thousand fertilizer B led to less leaf damage than fertilization with 1 part per thousand, and the growth of the most fertilized plants was, moreover, considerably greater (Fig. 1). Similar results were obtained by Wentzel [9], Björkman [1], etc.

The effect of liming was very different for the different species (Table 4). Cotoneaster lucidus, Crataegus sanguinea, Cytisus purgans, Picea abies and Pinus silvestris showed, on the whole, decreasing growth with increasing liming, while the growth of Alnus incana, Cornus 'Sibirica', Syringa vulgaris and Ulmus glabra increased with increasing liming. In addition, the effect of liming depended on the place of cultivation and the type of soil. The plants cultivated in Sarpsborg soil and those cultivated in Sarpsborg had the greatest need for lime.

The symptoms of damage varied from species to species. Some species, for example, Alnus incana, Cytisus purgans, Lonicera morrowii, Rosa 'Moje Hammarberg', Sorbus aucuparia and Pinus silvestris, reacted very strongly to SO_2 in the air (Fig. 3). In these species damage could first and foremost be observed as direct scorching of the leaves. Leaf damage already occurred after 3-4 weeks. First as a slight yellowing of the leaf blade but later also as a scorching of the leaf edge. The leaves curled up and became very rough. The plants cultivated in Sarpsborg showed from 50 to 70% less growth than those cultivated at the AUN.

Indirect damage, or the effect of the type of soil, appeared at the earliest after 8-10 weeks, and then as a slight yellowing of the leaf blade. Gradually the new leaves also became smaller than usual. Amelanchier sp., Cytisus purgans, Lonicera morrowii, Potentilla 'Longacre', Sorbus aucuparia and Ulmus glabra reacted very strongly to soil conditions (Fig. 4). In this case the growth of the plants cultivated in Sarpsborg soil was as much as 45% less than in mixed soil.

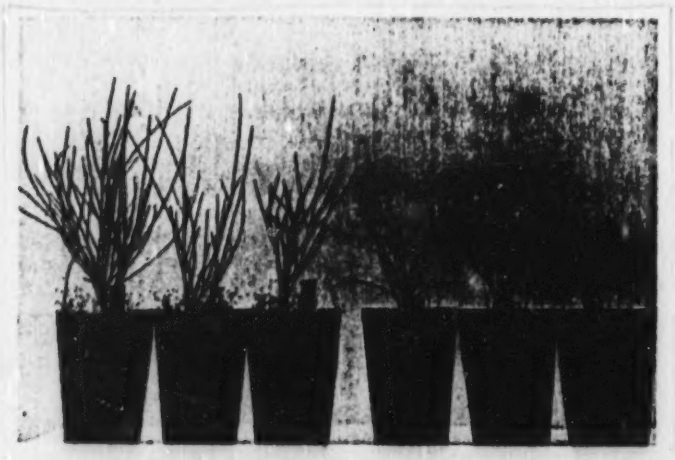

Fig. 3. Effect of place of growth on Cyticus purgans.
Left: Plants cultivated at the AUN
Right: Plants cultivated in Sarpsborg

On the basis of these experiments, the plants are divided into three groups:

1. SO_2-resistant:

Berberis thunbergii
Cornus 'Sibirica'
Elaeagnus commutata
Picea pungens 'Glauca'
Syringa vulgaris
Weigela 'Eva Rathke'

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Fig. 4. Effect of soil on growth of Sorbus aucuparia.
Left: Plants grown in SO_2-exposed soil
Right: Plants grown in mixed soil.

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2. SO_2-intermediate:

Amelanchier sp.
Betula pubescens
Cotoneaster lucidus
Crataegus sanguinea
Hippophaë rhamnoides
Picea abies
Potentilla 'Longacre'
Ulmus glabra

3. SO_2-sensitive:

Alnus incana
Cytisus purgans
Lonicera morrowii
Pinus silvestris
Rosa 'Moje Hammarberg'
Sorbus aucuparia

V. Summary

This report deals with sulfur dioxide damage to woody plants. Two different types of soil were used in the experiments. One from an SO_2-exposed place in Sarpsborg and one made of a mixture of unfertilized peat and powdered basalt. To the soil, different amounts of dolomitic limestone and fertilizer were added. The plants were grown in containers at an SO_2-exposed place in Sarpsborg and at the Agricultural University of Norway.

The effects of fertilizers, dolomitic limestone, soil and locality on growth are discussed, and the sulfur dioxide damage to each species is described. On the basis of these experiments, the plants are divided into three groups (see above).

Bibliography

1. Bjørkman, E., "The effect of fertilization on sulphur dioxide damage to conifers in industrial and built-up areas," Studia Forestalia Succica, Vol. 78, pp. 1-48, 1970.

2. Habjorg, A., "Effects of type of soil and fertilization on growth and development of Alnus incana (L.) Moench and Betula pubescens Ehrh. cultivated in pots in an SO_2-exposed place in Sarpsborg and at the Agricultural University of Norway in Ås," Meld. Norg. landbr. høgsk., Vol. 52, No. 1, 1972.

3. Lundstrom, H., "The effect of air pollution on the epiphytic flora of conifers in the Stockholm region," Studia Forestalia Succica, Vol. 54, 1968, pp. 1-54.

4. Oden, S., "Rain and air pollution -- its causes, course and effect in some environments," Statens naturvetenskapliga Forskningsråd. Ekologikomitten, Bulletin 1, Stockholm, 1968, 86 pp.

5. Selmer-Olsen, A. R. and Myhre, A., "An investigation of lead content in plant material along the Mosseveien," Meld. Norg. landbr. høgsk., Vol. 49, No. 26, 1970.

6. Skye, E., "Lichens and air pollution. A study of crypogamic epiphytes and environment in the Stockholm region," Acta Phytogeogr. Succ., Vol. 52, 1968, pp. 1-123.

7. Stöckhardt, A., "Investigation of young spruces and firs damaged by smoke from the Anton Metallurgical Works," Jahrbuch der Königl. Sächs. Akademie für Forst- und Landwirthe zu Tharandt, [Yearbook of the Royal Saxon Academy for Foresters and Farmers], 1853, pp. 169-172.

8. Wenn, K., "Damage to a pine forest around a pyrites mine," Tidsskr. Skogbr. Vol. 74, 1966, pp. 33-57.

9. Wentzel, K. F., "Are there trees impervious to emissions and smoke?" Forstarchiv, Vol. 35, 1964, pp. 49-51.